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Preliminary Report of Numerical Simulations of Intermediate Wavelength ExB Gradient Drift Instability in Ionospheric Plasma Clouds

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Two-dimensional numerical simulations of intermediate wavelength (100-1000m) ExB gradient-drift instability in local unstable regions of large F region ionospheric plasma clouds have been performed, using an initial one-dimensional (y), cloud geometry, for plasma cloud density gradient scale lengths L = 3, 6, 10 km. For conditions typical of 200 km barium releases, we find that linearly unstable modes saturate by nonlinear generation of linearly damped modes along the y-direction (parallel to ExB drift). In the nonlinear regime, power laws are observed ~~in the~~ → next page

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19. Abstract (Continued)

cont

one-dimensional parallel $P(k_y) \propto k_y^{-n_y}$ and perpendicular $P(k_x) \propto k_x^{-n_x}$ power spectra with $n_x \simeq$ 2-3 and $n_y \simeq$ 2-2.5. These results are compared with recent in situ experimental measurements and theoretical predictions.

CONTENTS

A

PRELIMINARY REPORT OF NUMERICAL SIMULATIONS OF INTERMEDIATE WAVELENGTH ExB GRADIENT DRIFT INSTABILITY IN IONOSPHERIC PLASMA CLOUDS

INTRODUCTION

Barium cloud injection experiments [Rosenberg, 1971; Davis et al., 1974] have provided much data concerning the dynamical evolution of plasma clouds in the F region ionosphere. The characteristic steepening, elongation, and striation of barium plasma clouds have been explained by applying the ExB gradient-drift instability [Simon, 1963] to plasma cloud geometries [Haerendel et al., 1967; Linson and Workman, 1970; Volk and Haerendel, 1971; Perkins et al., 1973]. Numerical solution of the fundamental fluid equations modelling the ExB instability in plasma clouds have reproduced not only the large scale gross observational features of plasma cloud evolution [Zabusky et al., 1973; Lloyd and Haerendel, 1973; Goldman et al., 1974; Doles et al., 1976; Ossakow et al., 1975, 1977] but also the spatial power spectra [Scannapieco et al., 1976] and minimum scale sizes of plasma cloud striations [McDonald et al., 1978]. However, the goal of these numerical simulations was to model the dynamics of the entire plasma cloud and wavelengths less than about a kilometer were not accurately resolved. But barium cloud experiments sponsored by the Defense Nuclear Agency have shown [Baker and Ulwick, 1978; Kelley et al., 1979] that the power spectra of the plasma cloud striations extends to wavelengths on the order of meters to tens of meters. It is of interest to numerically model these intermediate wavelength (100-1000 m) irregularities in order to compare with and supplement experimental observations.

Note: Manuscript submitted October 5, 1979.

In this preliminary report we present a two-dimensional numerical simulation of the intermediate wavelength $\underline{E}\times\underline{B}$ gradient-drift instability applicable to local unstable regions of large F region barium plasma clouds. The results of these simulations will be shown to be consistent with experimental and theoretical studies of striated barium clouds and, in many respects, similar to recent numerical simulations [Keskinen et al., 1979] of the intermediate wavelength collisional Rayleigh-Taylor instability in local regions of the bottomside of the equatorial F region ionosphere.

MODEL EQUATIONS

We wish to model two-dimensional $\underline{E}\times\underline{B}$ gradient-drift processes in local unstable regions of large ionospheric F region plasma clouds. The restriction to large clouds (large Pedersen conductivity compared with that of the background ionosphere) permits both the neglect of the cloud interaction with the background ionosphere (second level) and variations of cloud density and potential along the magnetic field lines. For wavelengths greater than the ion-gyroradius (approximately 10 m for Ba^+ in the twilight F region) a fluid description can be used which equations have been given previously [Perkins et al., 1973; McDonald et al., 1978; Chaturvedi and Ossakow, 1979].

By adopting a Cartesian coordinate system (x,y,z) with the geomagnetic field $\underline{B}$ in the z-direction, the ambient electric field $\underline{E}_o$ along the x-axis, and ignoring to lowest order electron and ion inertia, we can write after transforming to the $c\underline{E}_o\times\underline{B}/B^2$ frame

$$\frac{\partial n}{\partial t} - \frac{c}{B}\nabla\varphi_1 x\hat{z}\cdot\nabla n = \frac{2cT}{eB\kappa_e}\nabla^2 n \tag{1}$$

$$\nabla\cdot n\nabla\varphi_1 + \frac{T}{e}\nabla^2 n = \underline{E}_o\cdot\nabla n \tag{2}$$

where $n(x,y,t)$ is the plasma cloud ion density, $\varphi_1(x,y,t)$ is the electrostatic potential of the plasma cloud, $\kappa_e^{-1} = \kappa_{en}^{-1} + \kappa_{ei}^{-1}$, $\kappa_{e\alpha} = \Omega_e/\nu_{e\alpha}$, with ν_{en}, ν_{ei} the electron collision frequencies with neutrals and ions, respectively, and $T_e = T_i = T$ is the temperature. All other symbols retain their conventional meaning. By linearizing (1) and (2) and expressing $n = n_o + n_1$ with $n_1, \varphi_1, \propto \exp [i(k_x x + k_y y) + \gamma_{\underline{k}} t]$, $\underline{k}\cdot\underline{B} = 0$, $k L >> 1$ we find

$$\gamma_{\underline{k}} = (cE_o/BL)(k_x/k)^2 - (\nu_{en} + \nu_{ei})(k^2 C_s^2)/\Omega_e\Omega_i$$

where $L^{-1} = (1/n_o)(\partial n_o/\partial y)$, $k^2 = k_x^2 + k_y^2$, $C_s^2 = T/m_i$. We note that the growth rate $\gamma_{\underline{k}}$ maximizes for modes perpendicular to the density gradient ($k = k_x$) while the modes parallel to the density gradient ($k = k_y$) are damped by cross-field diffusion.

Numerical Simulations

By defining $n'(x,y) = n(x,y)/n_o(y)$, $\varphi_1'(x,y) = \varphi_1(x,y)/BL$, $x' = x/L$, $y' = y/L$, $t' = ct/L$, where $n_o(y)$ will be defined later, equations (1) and (2) can be written in dimensionless form as follows (after dropping primes for clarity)

$$\frac{\partial n}{\partial t} - \left(\frac{\partial \varphi_1}{\partial y}\frac{\partial n}{\partial x} + \frac{\partial \varphi_1}{\partial x}\frac{\partial n}{\partial y}\right) = - \frac{n}{n_o}\frac{\partial no}{\partial y}\frac{\partial \varphi_1}{\partial x}$$

$$+ \beta_1 \left(\frac{\partial^2 n}{\partial x^2} + \frac{\partial^2 n}{\partial y^2} + \frac{2}{n_o}\frac{\partial n_o}{\partial y}\frac{\partial n}{\partial y} + \frac{n}{n_o}\frac{\partial^2 n_o}{\partial y^2}\right) \quad (3)$$

$$\frac{\partial^2 \varphi_1}{\partial x^2} + \frac{\partial^2 \varphi_1}{\partial y^2} + \left(\frac{1}{n}\frac{\partial n}{\partial y} + \frac{1}{n_o}\frac{\partial n_o}{\partial y}\right)\frac{\partial \varphi_1}{\partial y} + \frac{1}{n}\frac{\partial n}{\partial x}\frac{\partial \varphi_1}{\partial x}$$

$$+ \beta_3\left(\frac{\partial^2 n}{\partial x^2} + \frac{\partial^2 n}{\partial y^2} + \frac{2}{n_o}\frac{\partial n_o}{\partial y}\frac{\partial n}{\partial y} + \frac{n}{n_o}\frac{\partial^2 no}{\partial y^2}\right) = - \beta_2 \frac{1}{n}\frac{\partial n}{\partial x} \quad (4)$$

where $\beta_1 = 2T/eBK_eL$, $\beta_2 = E_o/B$, $\beta_3 = T/eBL$ are dimensionless constants.

Equations (3) and (4) were solved numerically. The normalized plasma cloud density n/n_o in (3) was advanced in time using a variable time step flux-corrected predictor-corrector scheme [Zalesak, 1979] which is basically second order in time and fourth order in space. Equation (4) was solved for the cloud potential $\varphi_1(x,y)$ at each time step using a regridded Chebychev relaxation method [McDonald, 1977]. The results to be presented here were obtained using mesh of 64 x 64 grid points with constant spacing $\Delta x = \Delta y = 15$ m. Periodic boundary conditions were imposed on n/n_o and φ_1 in both the x and y directions. The parameters used in these simulations are typical of 200 km barium releases: $T = 10^3$ ^{0}K, $\Omega_e = 9 \times 10^6$ sec^{-1}, Ω_i (Ba^+) = 36 sec^{-1}, B = 0.5 G, E_o = 2mV/m, $\nu_{ei} = 2 \times 10^3$ sec^{-1}, ν_{en} = 150 sec^{-1} [Banks and Kockarts, 1973; McDonald et al., 1978].

Three different computer runs were made using different values of the equilibrium plasma cloud density gradient scale length L = 3, 6, 10 km where $n_o(y) = N_o\ (1 + y/L)$, N_o constant, is a steady state ($\partial/\partial t = 0$) solution of (1) and (2). The simulations were initialized with a two-dimensional perturbation of the form [*Chaturvedi and Ossakow*, 1979] $\delta n(x,y,t = 0)/n_o = A_{1,1} \sin k_y y \cos k_x x + A_{2,0} \sin 2k_y y$ with $k_x = k_y = 2\pi/960$ m with $A_{1,1} = 2 \times 10^{-5}$ and $A_{2,0} = 2 \times 10^{-6}$ (where $\delta n \equiv n-n_o$). We will now present the important nonlinear results of these simulations.

Fig. 1a gives an isodensity contour plot of $\delta n((x,y)/n_o$ in the x-y plane at t = 0 for L = 3 km. The initial contours describe a sequence of enhancements ($\delta n/n_o > 0$) and depletions ($\delta n/n_o < 0$) arranged in a checkerboard fashion. Fig. 1b and 1c show the evolution of $\delta n/n_o$ at t = 1500 and 1800 sec, respectively. The density fluctuation contours of $\delta n/n_o$ at t = 2000 sec are displayed in Fig. 1d where some elongation in the y-direction ($\underline{E}x\underline{B}$) and steepening can be seen. Similar contour development was also observed for the other two plasma cloud density gradient scale lengths L = 6, 10 km but on longer time scales.

Figs. 2a-b show representative one-dimensional power spectra both parallel $P(k_y)$ to the $\underline{E}x\underline{B}$ drift and perpendicular $P(k_x)$ in the nonlinear late time regime for L = 6 km. These power spectra are defined as follows

$$P(k_x) = \int dk_y \; | \; \delta n(k_x,k_y)/n_o|^2$$

$$P(k_y) = \int dk_x \; | \; \delta n(k_x,k_y)/n_o|^2$$

In the late time nonlinear state for the three scale lengths L = 3, 6, 10 km, $P(k_x) \propto k_x^{-n_x}$ and $P(k_y) \propto k_y^{-n_y}$ with $n_x \simeq 2$-3 and $n_y \simeq 2$-2.5 for wavelengths λ = 70-960 m. These spectral indices are consistent with recent in situ experimental measurements [Baker and Ulwick, 1978; Kelley et al., 1979] and analytical studies [Chaturvedi and Ossakow, 1979] of barium cloud striations.

Finally, Fig. 3 presents the time history of modes $A_{1,1}$ and $A_{2,0}$ for L = 10 km. Initially the $A_{2,0}$ mode along the E×B (density gradient) direction damps as given by linear theory. As the linearly unstable $A_{1,1}$ increases it nonlinearly triggers the growth of $A_{2,0}$. At late times these modes arrange themselves in approximate agreement with the nonlinear amplitudes predicted by Chaturvedi and Ossakow [1979]. Similar time development of $A_{1,1}$ and $A_{2,0}$ are observed for L = 3, 6 km.

SUMMARY

We have performed preliminary numerical simulations of the intermediate wavelength E×B gradient-drift instability in local unstable regions of large F region ionospheric plasma clouds using parameters typical of 200 km barium releases. For barium cloud density gradient scale lengths L = 3, 6, 10 km we find that: (1) linear unstable

modes saturate by nonlinear excitation of linearly damped modes along the y direction parallel to ExB drift and the initial cloud density gradient; (2) in the nonlinear well developed state elongation along the ExB direction is seen; (3) the one-dimensional power spectra $P(k_x) \propto k_x^{-n_x}$ and $P(k_y) \propto k_y^{-n_y}$ with $n_x \simeq 2\text{-}3$ and $n_y \simeq 2\text{-}2.5$ for wavelengths $\lambda = 70\text{-}960$ m. These results are consistent with recent barium cloud experimental measurements [Baker and Ulwick, 1978; Kelley et al., 1979]; support the nonlinear analytical work of Chaturvedi and Ossakow [1979]; and show furthermore the similarity between the ExB gradient drift instability in ionospheric plasma clouds and the collisional Rayleigh-Taylor instability in the equatorial F region ionosphere.

Future studies are planned which include variation of the parameters used in these simulations, addition of inertial effects, and inclusion of the cloud interaction with the background ionosphere (second level).

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References

Baker, K.D., and J.C. Ulwick, Measurements of electron density structure in barium clouds, Geophys. Res. Lett., 5, 723, 1978.

Banks, P.M., and G. Kockarts, Aeronomy (Part A), Academic Press, New York, 1973.

Chaturvedi, P.K., and S.L. Ossakow, Nonlinear stabilization of the $\underline{E} \times \underline{B}$ gradient drift instability in ionospheric plasma clouds, J. Geophys. Res., 84, 419, 1979.

Davis, T.N., G.J. Romick, E.M. Westcott, R.A. Jeffries, D.M. Kerr, and H.M. Peek, "Observations of the Development of Striations in Large Barium Clouds," Planet. Space Sci., 22, 67, 1974.

Doles, J.J., III, N.J. Zabusky, and F.W. Perkins, Deformation and Striation of Plasma Clouds in the Ionosphere 3. Numerical Simulations of a Multilevel Model with Recombination Chemistry, J. Geophys. Res., 81, 5987, 1976.

Goldman, S.R., S.L. Ossakow, and D.L. Book, On the nonlinear motion of a small barium cloud in the ionosphere, J.Geophys. Res., 79, 1471, 1974.

Haerendel, G., R. Lust, and E. Rieger, Motion of artificial ion clouds in the upper atmosphere, Planet Space Sci., 15, 1, 1967.

Kelley, M.C., K.D. Baker, and J.C. Ulwick, Late time barium cloud striations and their possible relationship to equatorial spread F, J. Geophys. Res., 84, 1898, 1979.

Keskinen, M.J., S.L. Ossakow, and P.K. Chaturvedi, Preliminary report of numerical simulations of intermediate wavelength collisional Rayleigh-Taylor instability in equatorial spread F, submitted to J. Geophys. Res., 1979.

Linson, L.M., and J.B. Workman, Formation of striations in ionospheric plasma clouds, J. Geophys. Res., 75, 3211, 1970.

Lloyd, J.H., and G. Haerendel, Numerical modeling of the drift and deformation of ionospheric plasma clouds and of their interaction with other layers of the ionosphere, J. Geophys. Res., 78, 7389, 1973.

McDonald, B.E., Explicit chebychev-iterative solution of nonself-adjoint elliptic equations on a vector computer, NRL Memo Report 3541, Nav. Res. Lab., Washington, D.C., June, 1977

McDonald, B.E., S.L. Ossakow, S.T. Zalesak, and N.J. Zabusky, Determination of minimum scale sizes in plasma cloud striations, Effect of the Ionosphere on Space and Terrestrial Systems, edited by J.M. Goodman, U.S. Government Printing Office, Washington, D.C., 1978.

Ossakow, S.L., A.J. Scannapieco, S.R. Goldman, D.L. Book, and B.E. McDonald, Theoretical and numerical simulation studies of ionospheric inhomogeneities produced by plasma clouds, Effect of the Ionosphere on Space Systems and Communications, edited by J.M. Goodman, U.S. Government Printing Office, Washington, D.C., 1975.

Ossakow, S.L., S.T. Zalesak, and N.J. Zabusky, Recent results on cleavage, bifurcation, and cascade mechanisms in ionospheric

plasma clouds, NRL Memo Report 3579, Nav.Res.Lab.,Wash.,DC,Aug.1977.

Perkins, F.W., N.J. Zabusky, and J.H. Doles III, Deformation and striation of plasma clouds in the ionosphere, 1, J. Geophys. Res., 78, 697, 1973.

Rosenberg, N.W., Observations of striation formation in a barium ion cloud, J. Geophys. Res., 76, 6856, 1971.

Scannapieco, A.J., S.L. Ossakow, S.R. Goldman, and J.M. Pierre, Plasma cloud late time striation spectra, J. Geophys. Res., 81, 6037, 1976.

Simon, A., Instability of a partially ionized plasma in crossed electric and magnetic fields, Phys. Fluids, 6, 382, 1963.

Völk, H.J., and G. Haerendel, Striations in ionospheric ion clouds, 1, J. Geophys. Res., 76, 4541, 1971.

Zabusky, N.J., J.H. Doles III, and F.W. Perkins, Deformation and striation of plasma clouds in the ionosphere. 2. Numerical simulation of a nonlinear two-dimensional model, J. Geophys. Res., 78, 711, 1973.

Zalesak, S.T., Fully multidimensional flux-corrected transport algorithms for fluids, J. Comp. Phys., 31, 335, 1979.

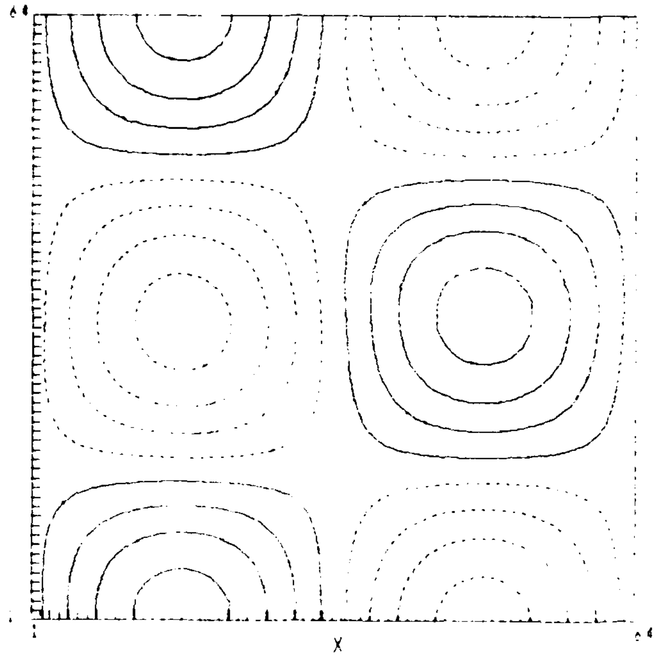


Fig. 1a

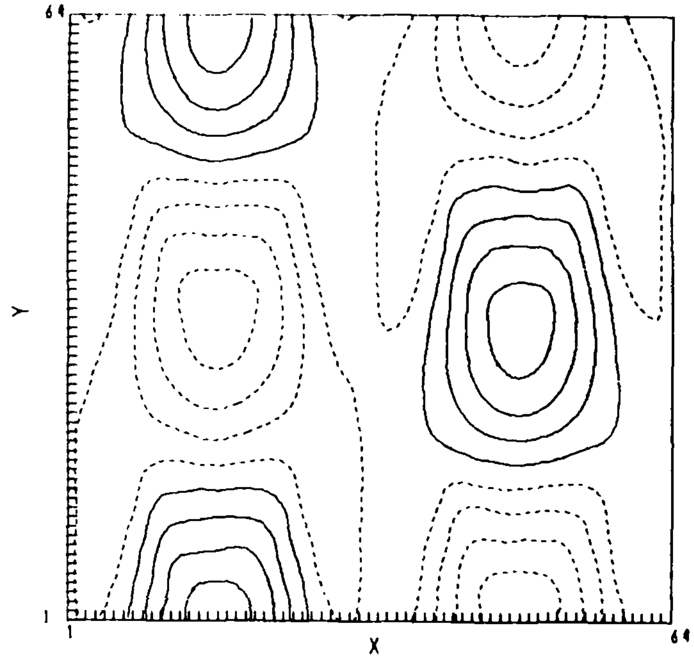
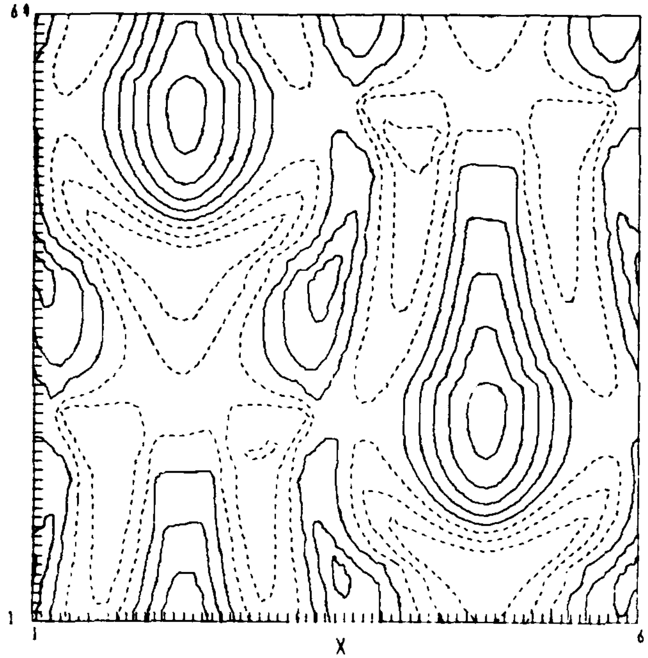


Fig. 1b

Fig. 1 - Isodensity contours of for L = 3 km at (a) t = 0, (b) t = 1500, (c) t = 1800, and (d) t = 2000 sec. Solid lines denote $\delta n/n_o > 0$; dashed lines denote $\delta n/n_o < 0$. All contours are evenly spaced with the y axis vertical (parallel to $\underline{E}_o \times \underline{B}$ and initial cloud density gradient) and x axis horizontal (perpendicular to $\underline{E}_o \times \underline{B}$). The tick marks represent grid point locations.



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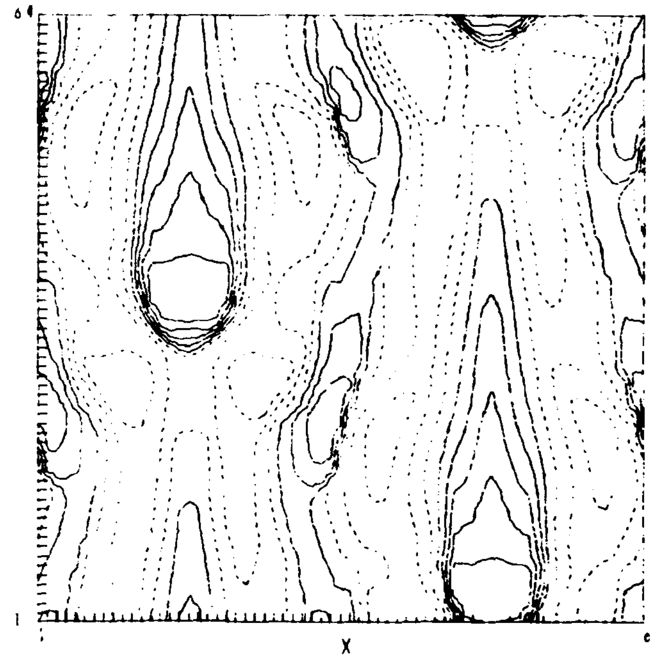

Fig. 1d

Fig. 1 - Isodensity contours of $\delta n/n_o$ for L = 3 km at (a) t = 0, (b) t = 1500, (c) t = 1800, and (d) t = 2000 sec. Solid lines denote $\delta n/n_o > 0$; dashed lines denote $\delta n/n_o < 0$. All contours are evenly spaced with the y axis vertical (parallel to $\underline{E}_o x \underline{B}$ and initial cloud density gradient) and x axis horizontal (perpendicular to $\underline{E}_o x \underline{B}$). The tick marks represent grid point locations.

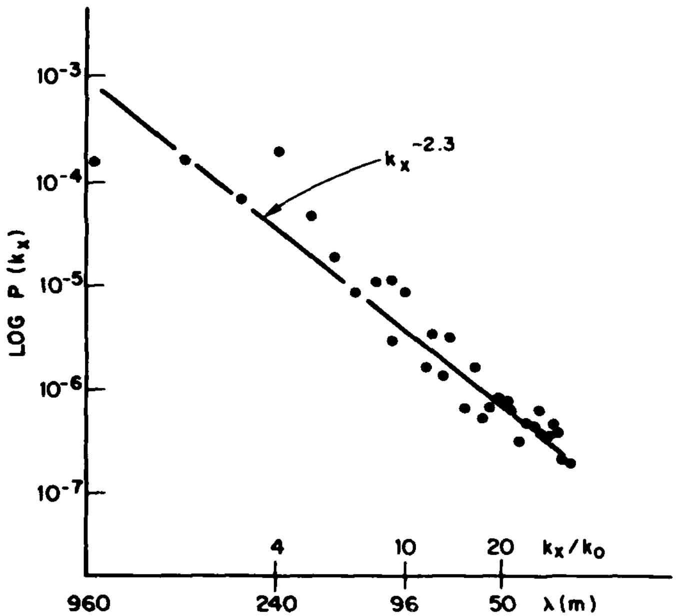

Fig. 2a

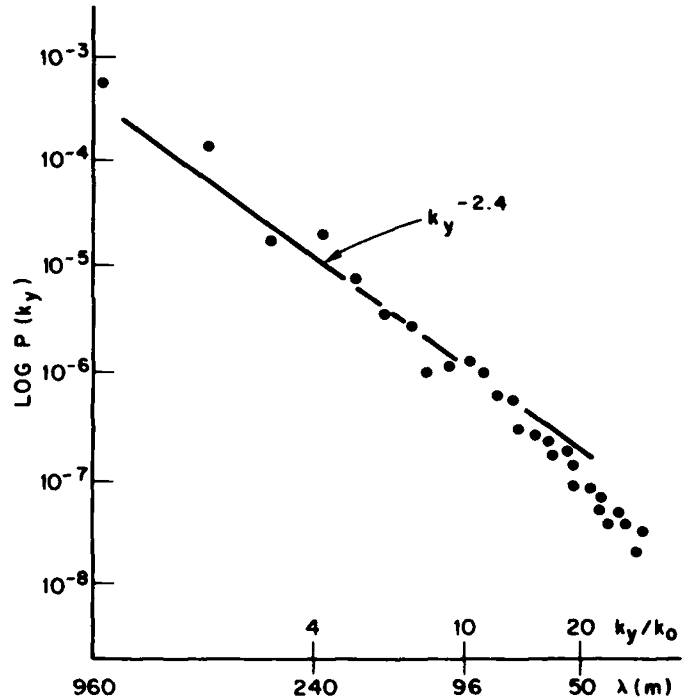

Fig. 2b

Fig. 2 - One dimensional perpendicular (a) $P(k_x)$ and parallel (b) $P(k_y)$ power spectra vs k_x and k_y, respectively, for L = 6 km in late time regime (t = 3150 sec.). Solid line is least squares fit to results from numerical simulation (dots) and $k_o = 2\pi/960$ m is the fundamental wave number.

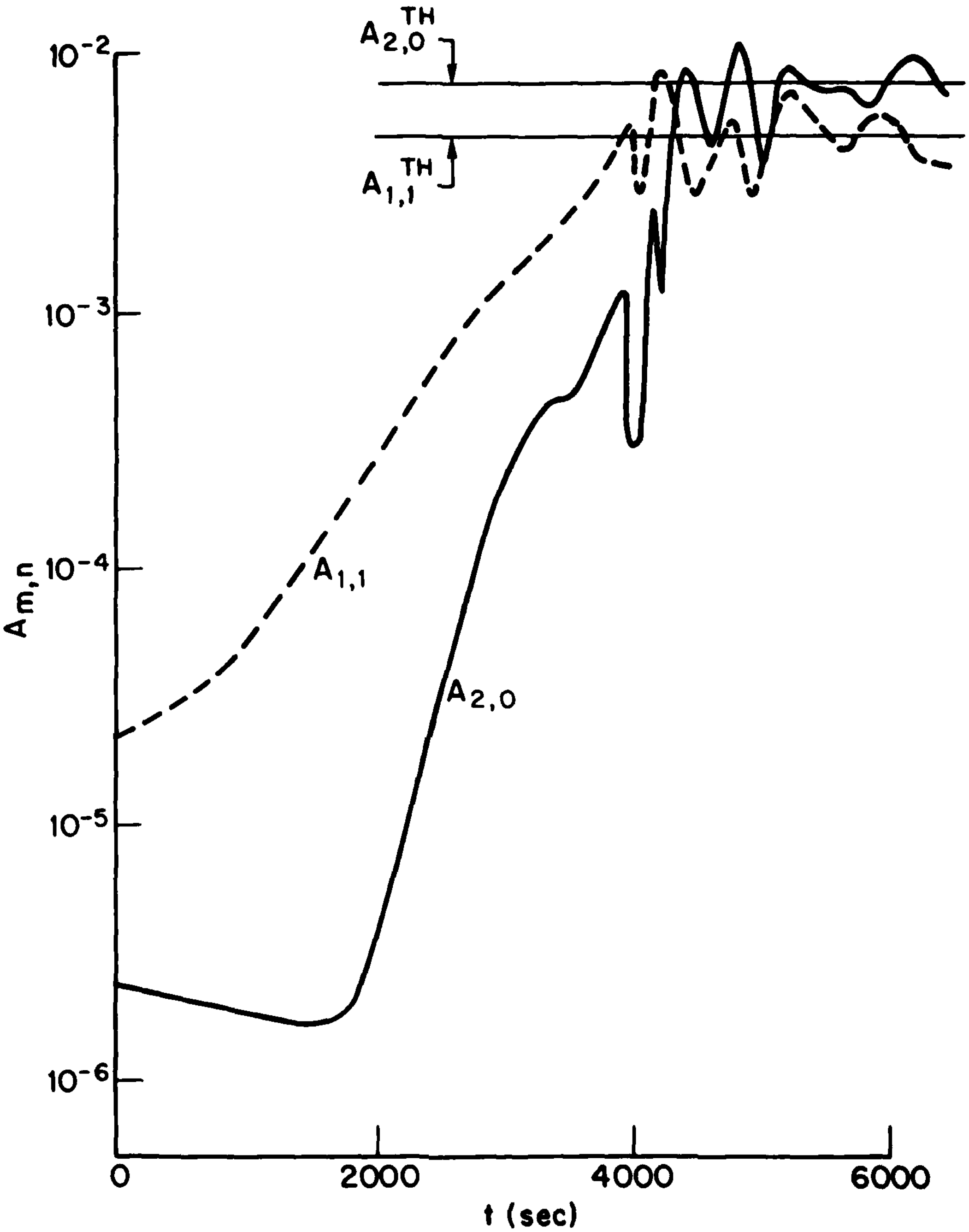

Fig. 3 — Time history of mode amplitudes $A_{2,0}$ (along initial cloud density gradient) and $A_{1,1}$ for L = 10 km where $A_{m,n} = A_{mk_{oy},nk_{ox}}$ and $k_{ox} = k_{oy} = 2\pi/960$ m. The horizontal solid lines are the steady state amplitudes $A_{1,1}^{TH}$ and $A_{2,0}^{TH}$ from the theory of Chaturvedi and Ossakow [1979].

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